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A Grid-Connected Dual Voltage Source Inverter with Power Quality Improvement Features

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ABSTRACT

This paper presents a dual voltage source inverter (DVSI) scheme to enhance the power quality and reliability of the micro grid system. The proposed scheme is comprised of two inverters, which enables the micro grid to exchange power generated by the distributed energy resources (DERs) and also to compensate the local unbalanced and nonlinear load. The control algorithms are developed based on instantaneous symmetrical component theory (ISCT) to operate DVSI in grid sharing and grid injecting modes. The proposed scheme has increased reliability, lower bandwidth requirement of the main inverter, lower cost due to reduction in filter size, and better utilization of micro grid power while using reduced dc-link voltage rating for the main inverter. These features make the DVSI scheme a promising option for micro grid supplying sensitive loads. The topology and control algorithm are validated through extensive simulation and experimental results.

INTRODUCTION

Technological progress and environmental concerns drive the power system to a paradigm shift with more renewable energy sources integrated to the network by means of distributed generation (DG). These DG units with coordinated control of local generation and storage facilities form a micro grid. In a micro grid, power from different renewable energy sources such as fuel cells, photovoltaic (PV) systems, and wind energy systems are interfaced to grid and loads using power electronic converters. A grid interactive inverter plays an important role in exchanging power from the micro grid to the grid and the connected load. This micro grid inverter can either work in a grid sharing mode while supplying a part of local load or in grid injecting mode, by injecting power to the main grid.

Maintaining power quality is another important aspect which has to be addressed while the micro grid system is connected to the main grid. The proliferation of power electronics devices and electrical loads with unbalanced nonlinear currents has degraded the power quality in the power distribution net- work. Moreover, if there is a considerable amount of feeder impedance in the distribution systems, the propagation of these harmonic currents distorts the voltage at the point of common coupling (PCC). At the same instant, industry automation has reached to a very high level of sophistication, where plants like automobile manufacturing units, chemical factories, and semiconductor industries require clean power. For these applications, it is essential to compensate nonlinear and unbalanced load currents.

Load compensation and power injection using grid interactive inverters in micro grid have been presented in the literature. A single inverter system with power quality enhancement is discussed in. The main focus of this work is to realize dual functionalities in an inverter that would provide the active power injection from a solar PV system and also works as an active power

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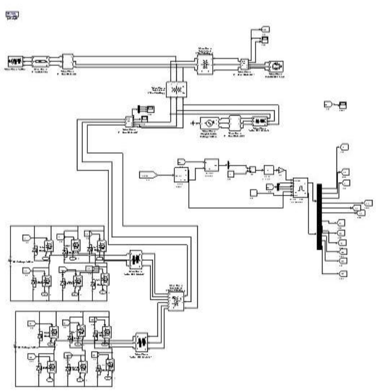
filter, compensating unbalances and the reactive power required by other loads connected to the system.

A voltage regulation and power flow control scheme for a wind energy system (WES) is proposed. A distribution static compensator (DSTATCOM) is utilized for voltage regulation and also for active power injection. The control scheme maintains the power balance at the grid terminal during the wind variations using sliding mode control.

A multifunctional power electronic converter for the DG power system is described in. This scheme has the capability to inject power generated by WES and also to perform as a harmonic compensator. Most of the reported literature in this area discuss the topologies and control algorithms to provide load compensation capability in the same inverter in addition to their active power injection. When a grid-connected inverter is used for active power injection as well as for load compensation, the inverter capacity that can be utilized for achieving the second objective is decided by the available instantaneous micro grid real power. Considering the case of a grid-connected PV inverter, the available capacity of the inverter to supply the reactive power becomes less during the maximum solar isolation periods. At the same instant, the reactive power to regulate the PCC voltage is very much needed during this period. It indicates that providing multi functionalities in a single inverter degrades either the real power injection or the load compensation capabilities.

This paper demonstrates a dual voltage source inverter (DVSI) scheme, in which the power generated by the micro grid is injected as real power by the main voltage source inverter (MVSI) and the reactive, harmonic, and unbalanced load compensation is performed by auxiliary voltage source inverter (AVSI). This has an advantage that the rated capacity of MVSI can always be used to inject real power to the grid, if sufficient renewable power is available at the dc link. In the DVSI scheme, as total load power is supplied by two inverters, power losses across the semiconductor switches of each inverter are reduced. This increases its reliability as compared to a single inverter with multifunctional capabilities. Also, smaller size modular inverters can operate at high switching frequencies with a reduced size of interfacing inductor, the filter cost gets reduced. Moreover, as the main inverter is supplying real power, the inverter has to track the fundamental positive sequence of current. This reduces the bandwidth requirement of the main inverter. The inverters in the proposed scheme use two separate dc links. Since the auxiliary inverter is supplying zero sequence of load current, a three-phase three-leg inverter topology with a single dc storage capacitor can be used for the main inverter. This in turn reduces the dc-link voltage requirement of the main inverter. Thus, the use of two separate inverters in the proposed DVSI scheme provides increased reliability, better utilization of micro grid power, reduced dc grid voltage rating, less bandwidth requirement of the main inverter, and reduced filter size. Control algorithms are developed by instantaneous symmetrical component theory (ISCT) to operate DVSI in grid-connected mode, while considering non stiff grid voltage. The extraction of fundamental positive sequence of PCC voltage is done by dq0 transformation. The control strategy is tested with two parallel inverters connected to a three-phase four-wire distribution system. Effectiveness of the proposed control algorithm is validated through detailed simulation and experimental results.

CIRCUIT DIAGRAM



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POWER QUALITY

The contemporary container crane industry, like many other industry segments, is often enamored by the bells and whistles, colorful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the foundation blocks. Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to support new crane installations.

To quote the utility company newsletter which accompanied the last monthly issue of my home utility billing: 'Using electricity wisely is a good environmental and business practice which saves you money, reduces emissions from generating plants, and conserves our natural resources.' As we are all aware, container crane performance requirements continue to increase at an astounding rate. Next generation container cranes, already in the bidding process, will require average power demands of 1500 to 2000 kW – almost double the total average demand three years ago. The rapid increase in power demand levels, an increase in container crane population, SCR converter crane drive retrofits and the large AC and DC drives needed to power and control these cranes will increase awareness of the power quality issue in the very near future.

CONTROLLING SYSTEM

The concept of instantaneous reactive power is used for the controlling system. Following this, the 3-phase voltage upon the use of the park presented by Akagi [24] has been transformed to the synchronous reference frame (Park or dq0 transformation). This transformation leads to the appearances of three instantaneous space vectors: Vd on the d-axis (real or direct axis), Vq on the q-axis (imaginary or quadrature axis) and V0, from the 3-phase voltage of Va, Vb and Vc. The related equations of this transformation, expressed in the MATLAB software, are as follows:

$$V_d = \frac{2}{3}(V_a \sin(\omega t) + V_b \sin(\omega t - \frac{2\pi}{3}) + V_C \sin(\omega t + \frac{2\pi}{3})) \qquad (2)$$

$$V_q = \frac{2}{3}(V_a \cos(\omega t) + \cos(\omega t - \frac{2\pi}{3}) + \cos(\omega t + \frac{2\pi}{3})) \qquad (3)$$

$$V_0 = \frac{1}{3}(V_a + V_b + V_c) \qquad (4)$$

A dynamic computation shows that the voltage oscillations in the connecting node of the flicker-generating load to the network are created by 3 vectors: real current (ip), imaginary current (iq) and the derivative of the real current with respect to time ($(\frac{di_p}{dt})$). In general, for the complete voltage flicker compensation, the compensating current (ic) regarding the currents converted to the dq0 axis is given as [3]:

$$i_c = j(i_q + i_p \frac{R}{X} f + \frac{1}{\omega}\frac{di_p}{d\omega} f + k)$$

where R and X are the synchronous resistance and reactance of the line and f is the correcting coefficient. The constant k is also used to eliminate the average reactive power of the network [3]. If the compensation current of the above equation is injected to the network, the whole voltage flicker existing in the network will be eliminated. Regarding the equation, related to the dq-transformation of the 3-phase-voltages to the instantaneous vectors, it is obvious that under the conditions of accessing an average voltage flicker, Vd and V0, the obtained values are close to zero and Vq is a proper value adapting to the voltage oscillation of the network.

This state of the 3-phase voltage flicker is presented in the following figures (simulated in the MATLAB Simulink package):

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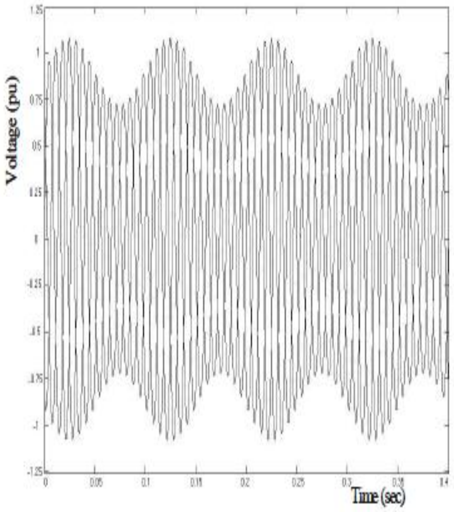


Figure 1: The voltage flicker exerted to the circuit

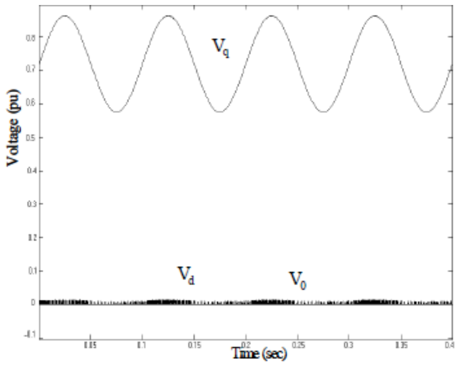
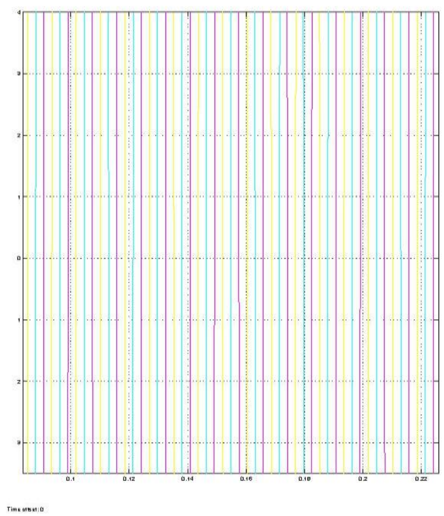
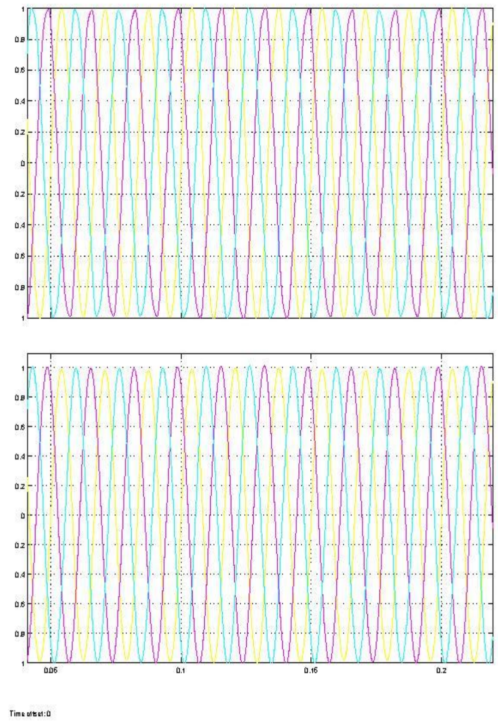
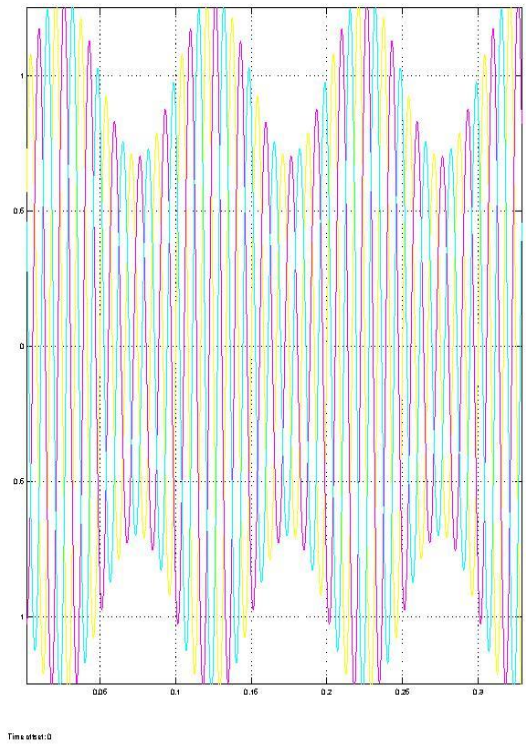


Figure 2: The instantaneous components of the 3-phase voltage flicker

SIMULATION RESULTS







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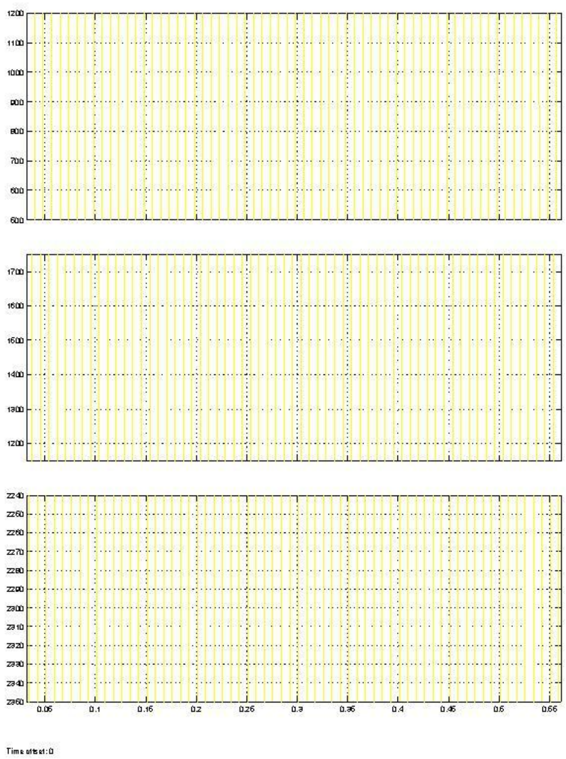

CONCLUSION

A DVSI scheme is proposed for micro grid systems with enhanced power quality. Control algorithms are developed to generate reference currents for DVSI using ISCT. The proposed scheme has the capability to exchange power from distributed generators (DGs) and also to compensate the local unbalanced and non linear load. The performance of the proposed scheme has been validated through simulation and experimental studies.

As compared to a single inverter with multi functional capabilities, a DVSI has many advantages such as, increased reliability, lower cost due to the reduction in filter size, and more utilization of inverter capacity to inject real power from DGs to micro grid. Moreover, the use of three-phase, three wire topology for the main inverter reduces the DC link voltage requirement. Thus, a DVSI scheme is a suitable interfacing option for micro grid supplying sensitive loads.

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Author Details:

I hereby declare that the project work entitled "**A Grid-Connected Dual Voltage Source Inverter with Power Quality Improvement Features"** submitted to the JNTU Hyderabad, is a record of an original work done by me under the guidance of **Mr. S.Sreenu**, Department of EEE, **SWAMI RAMANANDA THIRTHA INSTITUTE OF SCIENCE & TECHNOLOGY,** and this project work is submitted in the partial fulfillment of the Requirements for the award of the degree of Master of Technology in EEE. The results embodied in this thesis have not been submitted to any other University or Institute for the award of any degree.